Hookerton, North Carolina: A Small Community Rescued by Duckweed?

Paul Skillicorn
Carolina Kenaf Farmers Foundation

Rebecca Torres
Department of Geography
East Carolina University

The Hookerton Story

Hookerton, nestled on the high, southern bank of Contentnea Creek in Greene County is a metaphor for small, older towns in Eastern North Carolina. Main Street, punctuated by two blinking traffic lights, is lined with shuttered, boarded buildings and well-arbored, small wood and brick homes that date to the 30s, 40s and 50s. There's a functioning gas/service station, a branch bank, a tiny post office, "city hall" and a "latino-flavored" convenience store. The latter facility, crafted from an old, well-worn gas station, is now the only place in town selling food – or anything, for that matter. That it is "latino" in its emphasis is also a sign of the times. The barber shops, hardware stores, feed stores, grocery stores, appliance stores, furniture store, fish shop, butchers shop, department store, shoe store, bakery, cinema, café, hotel and restaurants are long gone – all victims of the "scale economies" that have given rise to the regional "dollar" strip retail malls, the Walmarts and K-Marts, regional "super" grocery stores, Pizza Huts, McDonalds' and Burger Kings (Creech, 1979; personal communication with Hookerton residents, 2001). The only visible reminder of the railway line are the trestle remnants that still show when Contentnea Creek is running low. Tragically, gone too are the doctors, dentists, clinics and the public schools. Indeed, it was the loss of Hookerton High School – a victim of Snow Hill (county seat) inspired "County Consolidation" – that signaled the beginning of Hookerton's long decline (personal communication with Hookerton residents, 2001).

Hookerton has shrunk to half the size it was during its heyday of the 40s, 50s and 60s, but most of the old names are still there: the Joneses, McLawhorns, Hills, Wootens, Albrittons, Creeches, Heads, Suggs, Murphys, Beamons, Barrows, Dawsons, Ginns, Turnages, Hardys and Moyes. The young folk simply keep drifting away. Some have migrated to the countless "double wides" artlessly crammed into the numerous "trailer" clusters or pseudo "townlets" that now litter Greene County's back roads, but most have moved "up and out" to Greenville, Raleigh, Charlotte and beyond. As the old folks say, "There's nothing left for them here in Hookerton" (personal communication with Hookerton residents, 2001).

In recent years, like many small North Carolina communities, Hookerton has seen a precipitous decline in its economic and population base. It is now only just hanging on from the marginal revenues derived from its three aged town-owned utilities: water supply, wastewater collection and treatment; and electric power supply. The town park and tennis court, cracked and sprouting weeds, have fallen into irreparable disrepair. The creaking community center is showing its age. The venerable, "non-standard" electric distribution utility, described by a regional CP&L (the dominant regional electric company) engineer as having "less than zero value," requires a complete "make-over"(personal communication with CP&L engineer, Kinston, NC, 2001). The town's water supply needs new wells, pumps, meters and distribution lines. Its sewage collector network has collapsed in spots, needs new lift pumps, requires new bridge supports and is heavily infiltrated by rainwater. Finally, Hookerton's ancient three-cell facultative lagoon wastewater treatment system is unable to meet even relaxed "30-30"[1] discharge standards (NC Environmental Management Commission, 1998). It is this latter "non-compliance" which has finally served to rouse the town from its seemingly inexorable slide towards the eventual loss of its municipal charter – a destination already apparently reached by its Greene county twin, Walstonberg, where a petition to revoke the town's charter is now being circulated among the town residents.

Initially, Hookerton's inability to meet its permitted "30-30" water quality discharge standard resulted in a succession of "fixes" prescribed by cognizant DENR (Department of Environment and Natural Resources) compliance engineers based in the "Little" Washington regional office. These suggestions ranged from chlorine application (pouring Sodium Hypochlorite or common bleach into the town's third lagoon) to intermittent discharge and finally extended aeration (personal communication Hookerton WWT manager, 2000). Nothing worked. Hookerton was finally urged to seek a "new system." After six years of inaction by the town, urging turned to "mandate," with imposition of a Special Order of Consent (SOC) by the North Carolina Environmental Management Commission (EMC). The SOC mandated construction, within three years, of a new system that would bring the town into compliance with its existing discharge permit. In the interim, the town's discharge standards were relaxed, but Hookerton was also strictly prohibited from engaging in any new "development." Failure to comply with both the terms and timetable dictated by the SOC would subject the town to a maximum possible daily fine of $2,000 (NC Environmental Management Commission, 1998).

With its SOC, Hookerton reluctantly gained membership to a notorious group of approximately 120 North Carolina communities that are now operating under a "development moratorium." As with Hookerton, all these communities – including county seat, Snow Hill and nearby Kinston, home to the Global Transpark – are prevented from providing wastewater treatment services to any new clients. This has the practical effect of freezing all commercial and domestic real estate development in each SOC affected community (NC Environmental Management Commission, 2001).

Having no option but to follow the dictates of the SOC, Hookerton instructed the local engineering company then handling its water and wastewater engineering needs, to develop plans for a new system. The firm recommended that Hookerton should subscribe to a portion of the new wastewater treatment capacity then being planned for construction in nearby Snow Hill. Hookerton would avail of that capacity through a "force main" pipeline designed to pump up to 60,000 gallons of raw wastewater up Contentnea Creek to the new Snow Hill facility.[2] The Snow Hill "regional" plant would also, under the engineering firm's proposal, accommodate some demand from housing developments located outside the Snow Hill municipal perimeter in adjacent areas of Greene County (Town of Hookerton, 1999b).

After reviewing the regional facility proposal, it became evident to the Hookerton mayor and Board of Commissioners that the town was being asked to subsidize buffer surplus wastewater treatment capacity which would, in the future, serve only the needs of Snow Hill and its Greene County "suburbs" (personal communication with Hookerton Mayor, 2000). The fixed, 60,000 GPD (gallons per day) capacity of the proposed Hookerton-Snow Hill force main would effectively prohibit Hookerton from benefitting from any of the proposed regional system's surplus capacity. The town commissioners also realized that, by committing to off-site treatment, Hookerton would lose its existing wastewater treatment permit – and with it, any ability to control its own destiny with respect to future growth. The Hookerton Board of Commissioners after much internal debate reached the conclusion that subscription by the town to the proposed regional wastewater treatment facility would have the effect of absolutely inhibiting any future growth for the town. This was, for the commissioners, a sobering realization, because they had also come to understand that the only way to salvage the town from its present steadily declining circumstance was to grow – to grow to a size that would transcend some of the scale economy thresholds now imposed upon them. They also understood that the only way the town could grow would be to offer potential new clients – both households and businesses – additional wastewater treatment capacity (personal communication with Hookerton Mayor, 2000). Hookerton chose, therefore, to explore alternative systems that would enable the town to move beyond its current (and proposed future) permitted wastewater treatment capacity of 60,000 GPD – options that would allow the town continued control over its future growth.

After considerable internal debate, and under the pressure of regional pipeline system stakeholders, the Hookerton Commissioners finally committed themselves to the regional system, despite its disadvantages. This was agreed to with one caveat: Hookerton would only agree to participate in the regional pipeline project if all costs associated with construction of the project were covered under a grant from the NC State Revolving Loan and Grants Fund. The town was privately assured by its engineering firm and DENR cognizant engineers that prospects for receipt of a full grant were excellent (personal communication with Hookerton Mayor, 2000).

In an inspired move, designed originally to mollify proponents of future growth and advocates of the selected alternative system, the Hookerton commissioners also agreed to a "parallel track" approach wherein the town would also apply for funding for that system from the NC Clean Water Management Trust Fund. Again, with a single, though somewhat more restrictive caveat: Hookerton would spend no resources whatsoever on the proposed alternative project – whether in application or implementation (personal communication with Hookerton Mayor, 2000).

Hookerton's "pipeline" proposal to the NC State Revolving Loan and Grants Fund was ultimately rejected – in two successive funding cycles. Reviewers deemed the projected $1.2+ million dollar project as providing "too little bang for the buck." Ironically, the alternative project – a proposed duckweed-based nutrient removal and wastewater polishing system – was approved for a $0.78 million grant from the NC Clean Water Management Trust Fund (Town of Hookerton, 1999a)[3].

Following a 12-month wait for DENR construction approval of its new duckweed wastewater treatment plant, Hookerton is now engaged in negotiating a construction and O&M agreement that should see the new plant fully operational by the summer of 2002. System design engineers have committed that Hookerton will, at that time, deliver the highest level of municipal wastewater treatment of any community in the United States.

"The Duckweed Project," as the alternative project has now come to be known, represents a radical departure from conventional wastewater treatment approaches now being prescribed for small communities in North Carolina. The project promises four unique innovations: (a) treatment of wastewater to a drinking water standard – namely to a much higher level than is required by law; (b) complete recycling of that treated effluent; (c) incremental, marginal need-based increase in future system capacity; and (d) a positive cash return on the "production and sale" of harvested duckweed – the new system's biological nutrient reduction agent (Town of Hookerton, 1999b).

Building on the potential for growth offered by the town's new wastewater treatment system, discussions are already engaged between the town, proximate landowners and outside developers and financiers that promise development of the first Greene County golf course "community" on the Hookerton periphery. The 300 "luxury homes," Lenoir Community College satellite campus and Greene County industrial park that are planned for construction within the community should be more than sufficient to reverse Hookerton's long decline and inject new commerce and vitality back into the town. Hookerton is clearly turning the corner (personal communication with Hookerton residents, 2001; personal communication with Hookerton Mayor, 2001).

Following a brief primer on wastewater treatment, and description of the "duckweed system" now being installed at Hookerton, the balance of this article is devoted to examining the effects these innovations are expected to have on Hookerton, as a town and community, and to discussing the implications of Hookerton's turnaround for other small communities throughout North Carolina.

A Wastewater Treatment Primer

Before embarking on a specific description of the Duckweed System, it is instructive to gain a basic understanding of wastewater treatment.

The simple objective of every municipal wastewater treatment system is to render the final, discharged effluent more pure than when it entered the facility, and to do so in a manner that meets minimal standards imposed by state and national regulatory authorities. The treatment function typically contains three basic elements: (a) removing solids, (b) removing chemicals (principally nutrients) and dissolved solids and, finally, (c) killing pathogens. Every wastewater treatment plant will, in some fashion, attempt to achieve the first two. Formal attention to the latter, killing pathogens, is also rapidly becoming an essential element in every modern system. Critical ancillary tasks include "dealing" with the solids, once removed, and the treated wastewater once it has passed through the system.

The entire spectrum of wastewater treatment "approaches" can be divided between "passive" and "active" systems – with the former occupying relatively large amounts of land and using little energy and the converse characterizing the latter. Active systems are, in general, capable of delivering a marginally higher level of treatment than passive systems. The basic rule of thumb had always been to employ passive systems in circumstances where land values are low and capital constrained; and active systems where land values are high and financing readily available. With minor exceptions, however, this is no longer the case. In more affluent societies able to indulge higher levels of concern for the environment, rapidly tightening effluent standards are now rendering most passive systems infeasible – systems such as, for instance, Hookerton's aging facultative lagoon complex.

Removing solids, in both active and passive systems involves two stages. In the first stage solids carried in the influent wastewater must be removed from the waste stream. Solid objects having high integrity are easily removed through a simple screening device. Those which break down to fine constituents must, in some fashion, be precipitated from the waste stream. Most passive systems employ a large, "primary" lagoon where influent solids gradually sediment on the bottom, where they subsequently remain, slowly decaying, for the active life of the system. Active systems, on the other hand, employ chambers of various configurations specifically designed to optimize influent solids settling and concentration for subsequent removal.

Second stage solids removal involves purging biological nutrient uptake agents. In truly passive systems this means precipitation of phytoplankton – principally algal species. This painstakingly slow process is achieved by extended hydraulic detention in successive lagoons wherein increasingly nutrient-deprived algae gradually expire and slowly settle to the lagoon bottom. Second stage solids removal in active systems, on the other hand, involves extraction of aerobic bacteria species. This is a somewhat more efficient process than removing algae, because aerobic bacteria expire quickly when deprived of both nutrients and oxygen. The whole process can be achieved with detention times of less than 24 hours in a deep quiescent, usually circular chamber called a clarifier..

Nutrient and dissolved solids removal in both active and passive systems is, with minor exception, achieved by promoting the growth of a select, targeted family of organisms. So called "activated sludge" systems employ a wide range of aerobic bacteria to uptake nutrients. Most lagoon systems achieve the same function with algae. Occasionally, lagoon systems have also been adapted to promote growth of macrophytes such as water hyacinth and duckweed species. Constructed wetlands, the modern passive system successor to lagoons, take a more eclectic approach to nutrient uptake, employing a wide variety of rooted and floating macrophytes in addition to zoo- and phytoplankton. As we have already described (above), algae, bacteria and other biological nutrient removal agents must subsequently themselves be removed from (or separated from) the wastewater to effect treatment. In the case of truly passive lagoon and wetland systems, treatment efficiencies are degraded by ongoing release by decaying organisms of nutrients back into the wastewater stream.

Sterilization of treated effluent employs one, or a combination of three systems: traditional chlorinization, ozone contact or ultraviolet irradiation. Use of chlorine is increasingly frowned upon because it creates trihalomethanes, a family of potent carcinogens, from residual organic compounds still present in the final effluent. Effectiveness of ultraviolet treatment is a function of effluent clarity. With increasingly higher levels of treatment (and hence discharge effluent clarity) now being achieved, it is rapidly becoming the system of choice. Employed with great success sterilizing swimming pool water, ozone is also finding applications in a significant number of large scale commercial systems – many in combination with ultraviolet irradiation.

Dealing with the vast quantities of bacterial sludge produced by active, aerobic systems, has always been one of the most difficult and costly elements of modern, mechanical wastewater treatment. Despite the theoretical potential for converting sludge to a highly remunerative organic soil enhancer, no large wastewater treatment facility has ever succeeded in covering a significant portion of its O&M cost (not to mention capital costs) through commercial sale of such products. "Milorganite" a fertilizer product of Milwaukee's municipal wastewater treatment plants has garnered great conceptual acclaim from environmental circles throughout the United States, but never the widespread consumer acceptance necessary to make it a true commercial success.

Duckweed Wastewater Treatment

The "alternative" duckweed wastewater treatment system being installed by the town of Hookerton falls somewhere in the middle of the "active – passive" continuum. It occupies significantly less space than a typical facultative lagoon system, but also uses much less energy than an activated sludge plant. As with any wastewater treatment plant, duckweed systems must deal with influent solids. The Hookerton system will simply "leave in place" the existing primary lagoon which is now effectively serving to sediment influent solids. Duckweed systems constructed in other communities that are unable to "build on" existing lagoon complexes will typically employ aggressive solids separation and digestion approaches now favored by the aquaculture industry. These employ a number of centrifugal devices arrayed in series to remove solids from the main wastewater stream. Those solids are subsequently treated in a 2-phase (thermophilic/mesophilic) continuous flow-through anaerobic digester which reduces their volume by 90%-95% while also "recovering" their inherent nutrient constituents for subsequent "recycling" through harvested duckweed plants.

The "guts" of a duckweed wastewater treatment system is the duckweed system itself: an array of greenhoused bioreactors growing a continuously harvested duckweed crop (see figures 1. and 2.). This biological nutrient removal system is analogous to the bacteria in activated sludge systems and the algae in passive lagoon systems. It holds significant technical advantages over both. Duckweed can remove nutrients, metals and both organic and inorganic compounds from water with higher efficiency than either bacterial or algal systems, and, unlike either of those two systems, it is trivial to remove, or "harvest" from the wastewater once it has performed its treatment function. A further advantage of duckweed is that it is highly nutritious and therefore valuable as an additive in livestock and fish feeds (Skillicorn, 1993).

In combination, these characteristics give duckweed an overwhelming advantage over all conventional wastewater treatment systems now in operation. It is instructive to put some numbers to that advantage. With respect to nutrient removal, continuously harvested duckweed systems have been shown reliably to bring combined ammonia and nitrate nitrogen to below 0.2 mg/l in treated discharge (Alaerts, 1996). This is approximately one thirtieth the level achieved by the average modern activated sludge plant (6+ mg/l combined nitrate and ammonia nitrogen), and one tenth the level expected of a state-of-the-art SBR (Sequencing Batch Reactor) system[4] (2+ mg/l combined ammonia and nitrate nitrogen). Relative performance for difficult-to-remove phosphorus, heavy metals and toxic organic and inorganic compounds is even better, with typical advantages over SBR systems exceeding ten to one.

The ease with which floating duckweed plants can be removed from water gives duckweed systems a significant capital and O&M cost advantage over all bacterial system (see figure 3). In particular, it obviates the need for expensive clarification and sludge concentration devices and processes. Continuously skimming duckweed from the surface of a "duckweed bioreactor" is a trivial task. Having been removed from the waste stream, duckweed, a living, odor-free leafed macrophyte is then amenable to easier handling and subsequent "processing" than is the malodorous dead bacterial sludge product of an activated sludge wastewater treatment plant.

Harvested wet, duckweed plants contain approximately the same moisture and nutritional value as whole milk. Dry weight protein content of "well fed"

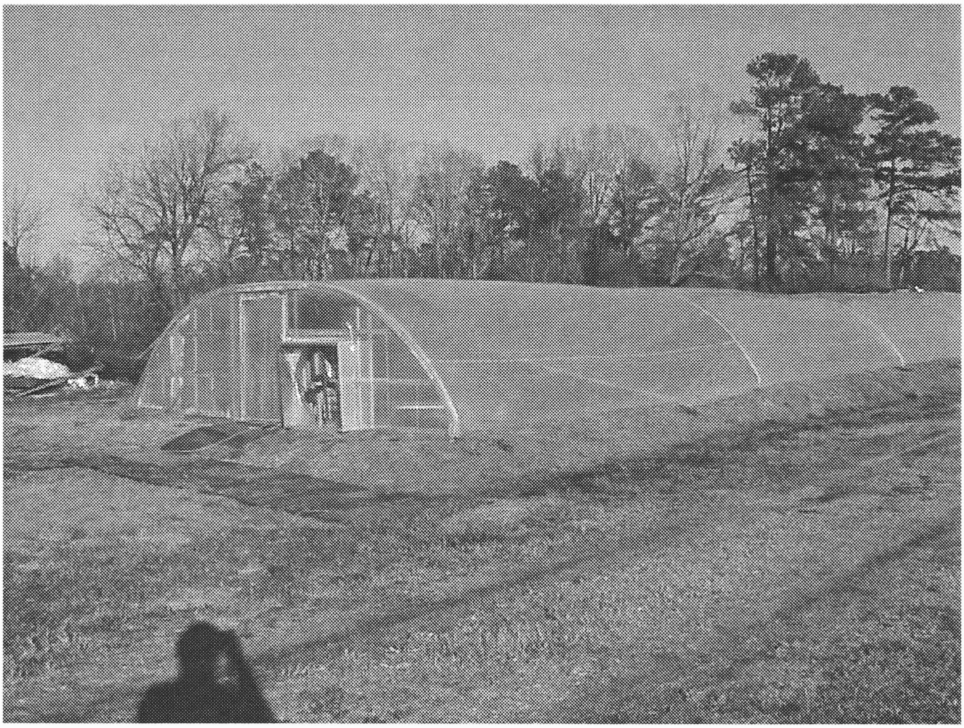

Figure 1. Greene County, North Carolina duckweed greenhouse showing inflated plastic covering and excavated earthen tank.

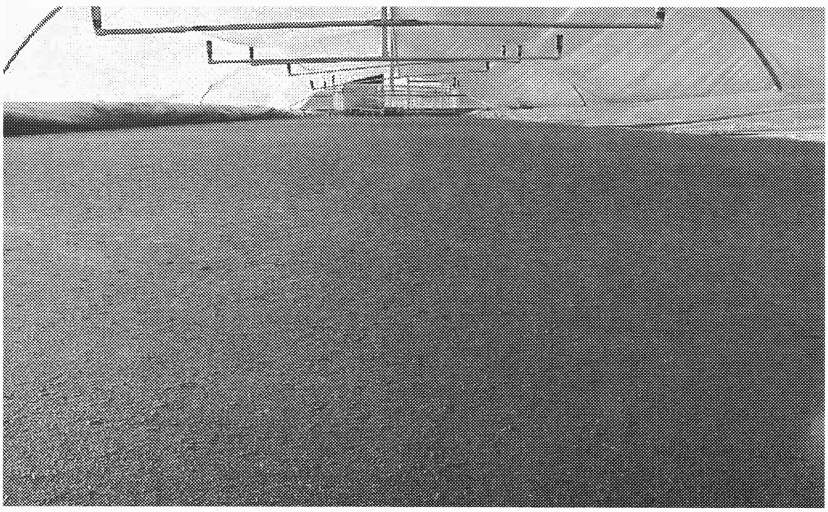

Figure 2. Greene County, North Carolina duckweed greenhouse showing interior configuration and duckweed "mat" cover.

duckweed plants can exceed 45% (Skillicorn, 1993). Their protein, which is high in "animal" amino acids methionine and lysine, has significantly higher market value than that produced by soybeans. Duckweed contains significantly more mineral and vitamin value than either milk or soybeans. Vitamin A and beta carotene levels, for example, exceed that of any other known plant species. Duckweed plants also have high levels of folic acid and the valuable feed industry pigment xanthophyll.

Recent developments pioneered at NC State University have also shown duckweeds to be particularly amenable to genetic engineering. Scientists have demonstrated that a wider range of human, animal and plant proteins can be "introduced" into duckweed through conventional recombinant DNA techniques than are accommodated by either e-coli bacteria or yeast, today's common "engines" for production of genetically engineered proteins. This makes very real the prospect of duckweed-based wastewater treatment plants serving as "factories" to produce, in particular, a range of valuable industrial enzymes such as xylanase, laccase and cellulase. The value of duckweed's ease of engineering is further enhanced by the plant's favored means of reproduction – cloning. Once "engineered," an enzyme producing duckweed variety can continue to be cloned indefinitely (Personal communication, Biolex executives, 2001).

Figure 1. depicts a typical duckweed "greenhouse" configuration. The interior "bioreactor" comprises a simple, lined tank allowing maintenance of a 2.5' deep water column. A typical tank configuration is 100' x 17' x 3'. The 2-ply plastic greenhouse borrows its design from systems now employed in the surrounding counties to produce tobacco seedlings. Side curtains are not employed in order to maximize control over internal temperatures. The Hookerton design features a dual parallel tank configuration under a single 100 x 35' greenhouse (Town of Hookerton, 2001a). While earthen tank construction is preferred, concrete construction can be employed in circumstances where available space is constrained. A single 1000 watt fan provides adequate system ventilation to ensure crop maintenance within a desired temperature range during summer months.

Figure 2. depicts a typical duckweed greenhouse interior. It is noteworthy that surface coverage by the duckweed "mat" is comprehensive. This ensures complete blockage of light penetration into the water column and effective inhibition of phytoplankton growth which, in turn, minimizes presence of suspended solids in treated discharged effluent. Spray nozzles employ treated, recycled wastewater to effect a variety of specific "mat" maintenance functions.

Figure 3. depicts a duckweed harvester employing a simple "capture" method to remove a portion of the floating duckweed mat from the bioreactor. The harvester additionally serves to redistribute the mat over the bioreactor surface on the return leg. Fully automated hydraulic harvesting systems will be deployed in the new Hookerton facility (Town of Hookerton, 2001a).

Figure 4. depicts the clarified, treated effluent output from a duckweed-based swine waste treatment facility based in Greene County, North Carolina. Discharge quality for the facility exceeded, by a significant margin, the strictest standards imposed on treatment of municipal wastewater in North Carolina.

Figures 5. depicts the three main duckweed genera, *Spirodela*, or giant duckweed, *Lemna*, or common duckweed, and *Wolffia*, the smallest known flowering plant. *Spirodela* species, averaging 0.5 cms in diameter, are characterized by a "tuft" of small roots emanating from their ventral surfaces. *Lemna* species, averaging approximately half the diameter of *Spirodela* species, are characterized by a single root. Tiny *Wolffia* species have no roots whatsoever and effect a rotund shape, as opposed to both *Lemna* and *Spirodela* which have relatively flat fronds. Despite their ability to produce fruit and seeds, it is duckweeds' ability to reproduce vegetatively by cloning which contributes most to their remarkable reproduction and growth rates. Each "mother" frond can produce between seven and ten daughter fronds during its life cycle.

The Implications of Hookerton's Adoption of Duckweed?

Two questions are posed: "What is the implication to Hookerton of its commitment to duckweed-based wastewater treatment?" and, by extension, "What significance does this hold for similar communities in North Carolina and across the South?" Before delving into these questions, it is useful to gain some understanding of the wastewater treatment

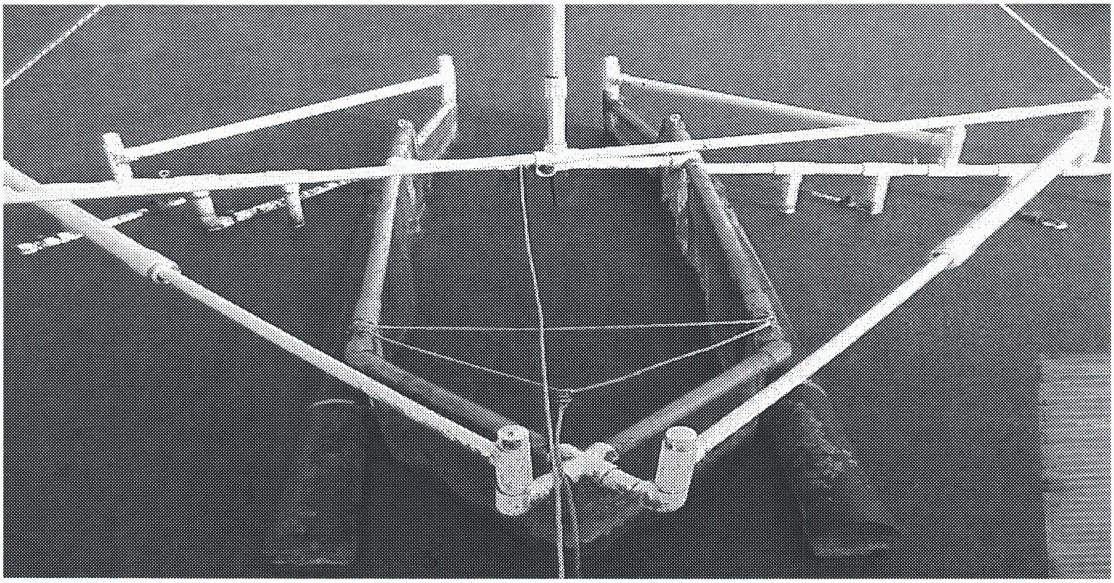

Figure 3. Duckweed "capture" harvester.

Figure 4. Greene County, North Carolina showing treated swine waste being discharged from a duckweed greenhouse.

equation in North Carolina. Indeed, it is Hookerton's need to react to that equation which now dominates the town's current circumstance and future prospects. Hookerton's situation is not unique in that respect. During the coming decade every small town in North Carolina, indeed, across the nation, will be faced with the same issues that Hookerton is now confronting.

North Carolina state environmental authorities have estimated that it will cost approximately $10 billion during the coming decade to meet the state's requirements to upgrade water, sewer and wastewater treatment requirements (personal communication, NC Rural Center, 2001). Of this requirement, the major share will be required to bring aging wastewater treatment plants into compliance with tightening state standards. The vast majority of old systems are deployed in small communities such as Hookerton that have experienced little growth in recent years. As a general rule of thumb, scale economies dictate that acquisition of "conventional" technology able to deliver advanced tertiary effluent such as is already required for Neuse River basin communities will cost small communities more than twice what larger (25,000+ populations) towns must pay for the same treatment system performance (See figure 6.). Small communities lacking an industrial tax base, many already burdened with extraordinary "Electricities debt",[5] either cannot borrow or must pay premium rates if allowed to do so (See figure 7.). Further, these same communities cannot deliver on the critical "bang-for-buck" criterion applied by the state revolving loan and grants fund when its limited pool of capital resources is allocated.

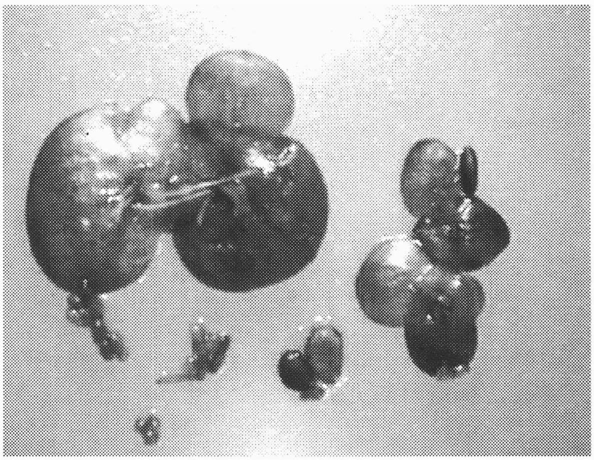

Figure 5. Three main duckweed genera, shown from the bottom: *Wolffia* (smallest), *Lemna* (medium) and *Spirodela* (largest).

It is instructive to examine Hookerton's specific circumstance. Hookerton is currently saddled with a $4.967 million dollar bond debt for its 0.155% share of the nuclear power plant capacity it bought collectively with its North Carolina Eastern Municipal Power Agency partners (personal communication with Electricities executives, 2001). Paying back this debt over 30 years at a 6% rate of interest represents a $147 monthly burden to each of the town's 205 families – that is *before* they even pay their electricity usage bill. The town's entire electric distribution infrastructure is in need of replacement. Doing so would place a similar monthly burden on each family. If Hookerton wished to develop a conventional wastewater treatment system sufficient to attract 300 luxury homes, a golf course and country club, a satellite college campus and a new industrial park, it would need to double its existing capacity. This would immediately subject the town to the new Neuse River advanced tertiary treatment standards. Constructing a new 120,000 GPD advanced tertiary treatment system would cost the town an expected $30 per gallon of installed capacity, or $3.6 million, and impose a capital cost burden of approximately $36 per month on each of the town's 500 (200 current and 300 new) homes – *before* operations and maintenance costs are figured in. Given its inability to qualify for previous grants from the DENR Revolving Loan and Grants Fund, the town would be unlikely to obtain grant funding. Borrowing the funds when it already has almost $5 million in existing nuclear power plant debt would certainly be problematic. Hookerton would clearly have great difficulty developing a favorable circumstance which would allow it to grow. Indeed, even were it able to obtain the financing it sought, the significantly higher rates the town must already charge for the electricity it delivers, combined with higher than average rates for

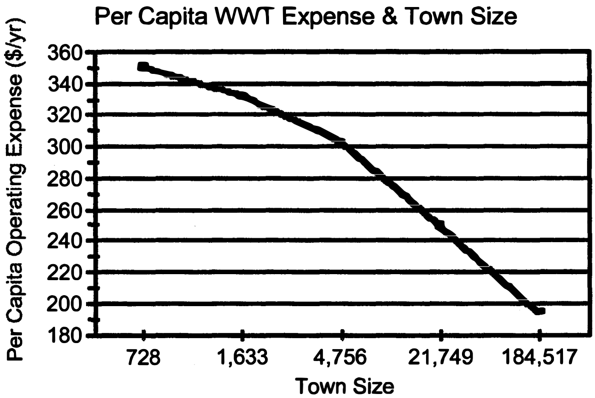

Figure 6. Source: 2000 Budgets for Pink Hill, Snow Hill, Mt. Olive, Goldsboro, Cary and Raleigh, as obtained in 2001 from the NC Treasury Department.

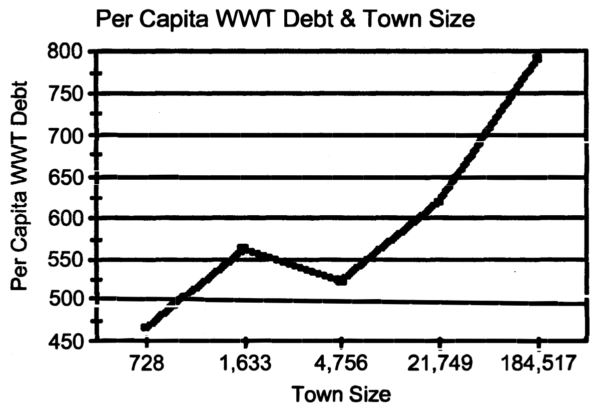

Figure 7. Source: 2000 Budgets for Pink Hill, Snow Hill, Mt. Olive, Goldsboro, Cary and Raleigh, as obtained in 2001 from the NC Treasury Department.

water and wastewater would certainly deter most industrial clients and also probably most potential new residents.

The duckweed system Hookerton is now installing will cost the town nothing. Most of the new system capital costs are being covered by a grant from the NC Clean Water Management Trust Fund under its program to support "innovation" in wastewater treatment throughout North Carolina (Town of Hookerton, 1999a). The balance of capital costs will be invested by the company that will both build and operate the new system (personal communications, Proterra executives, 2001). Despite the town having just constructed a wastewater treatment plant capable of delivering the highest effluent discharge quality in the state, there will be no impact whatsoever on Hookerton's existing 205 families. Assuming the same development scenario outlined above, doubling Hookerton's duckweed wastewater treatment capacity to 120,000 GPD would, at $8.00 per additional installed gallon of capacity, cost approximately $480,000. This would impose a capital cost burden of $5 per family on the town's 205 current and 300 new households, raising monthly wastewater treatment costs to around $20 per family. In an era of sharply rising water and wastewater fees these rates should remain among the lowest in the state. While electricity fees will continue to remain a significant liability for Hookerton, particularly with potential industrial clients, the town is considering "reaching out" with its new "expandable"[6] wastewater treatment utility to provide services to neighboring communities and housing clusters. Revenues derived from provision of such services could help to defray the town's high electricity rates.

Going one step further, Hookerton is seeking to negotiate a "profit sharing" arrangement with its wastewater contractor wherein the town will receive a percentage of profits from the sale of duckweed and duckweed derived products produced at the Hookerton facility. By offering the management company a remunerative "partnership" in its municipal utility, it is also providing a clear incentive for that company to drive the process of bringing in new clients – both "in-town" and remote clients. With the management company aggressively marketing its new, low cost utility, it is not unlikely that Hookerton may soon begin providing wastewater treatment services to new clients located in the nearby Global Transpark as well as in rural communities and housing clusters in Greene County. It is even conceivable that the town can provide truly "remote" wastewater treatment services to both industrial and residential clients located in the growing fringes of neighboring cities like Kinston, Goldsboro, Greenville and Wilson. This would be achieved by building remote treatment facilities constructed in or proximate to those communities.

If Hookerton is able to break through and achieve significant positive growth, it will serve as a powerful model for the thousands of small towns and communities that now share a similar fate. Perhaps more significantly, it will serve to arrest – possibly even reverse – the continued migration of people from those communities to the state's urban/suburban growth poles. If this can be made to happen, the impact on the state budget will be profound. A comparative examination of state subsidies versus community size (See figure 8.), suggests that it costs the state more than twice as much to support a person in large cities such as Raleigh and Charlotte as it does in Hookerton and like communities.

Duckweed wastewater treatment systems, by lowering the cost of wastewater treatment, increasing the

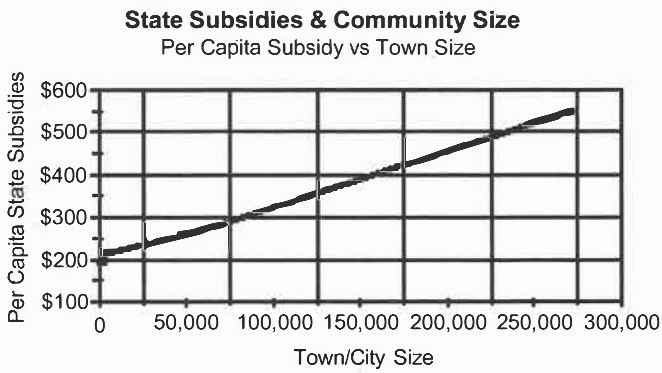

Figure 8. Source: 2000 Budgets for Pink Hill, Snow Hill, Mt. Olive, Goldsboro, Cary and Raleigh, as obtained in 2001 from the NC Treasury Department.

quality of treated effluent and generating revenues from duckweed harvested from those systems, can serve as an engine by which America's small communities may reverse their contemporary history of misfortune. Adoption of duckweed systems and provision of inexpensive wastewater treatment capacity can serve again to make America's small communities attractive places in which to live and to work.

End Notes

1 30 mg/l BOD (Biochemical Oxygen Demand), a measure of organic content; and 30 mg/l TSS (Total Suspended Solids), a measure of turbidity, is a standard treatment level prescribed for municipal wastewater treatment plants throughout the world. Recently issued NPDES discharge permits in North Carolina are mandating standards which have the effect of requiring both BOD and TSS reduction to below 5 mg/l, respectively.

2 Hookerton is presently permitted to treat 60,000 gallons of wastewater per day.

3. Author Paul Skillicorn is an environmental engineer with expertixe in duckweed-based wastewater treatment. He has volunteered his assistance to the town of Hookerton in planning and designing the town's new duckweed wastewater treatment plant.

4 SBR systems employ sophisticated "sequenced" aerobic and anoxic reactions in a batch process to achieve exceptionally high treatment efficiencies.

5. Under "Electricities" numerous North Carolina Municipalities were induced to directly acquire ownership in two nuclear power plants then being constructed by CP&L and Duke Power.

6. Having a low installed capacity cost, and amenable to incremental expansion, duckweed systems can "expand" as necessary to meet specific customer requirements.

References

Alaerts, G. J., Mahbubar, M. R. and **P. Kelderman**. (1996). "Performance analysis of a full-scale duckweed-covered sewage lagoon," Water Research, Vol. 30, No. 4, 843-852.

Biolex executives. (2001). Personal communication, Biolex, Pittsboro, NC.

City of Cary. (2001). Cary 2000 Budget, NC Treasury Department, Raleigh, NC.

City of Goldsboro. (2001). Goldsboro 2000 Budget, NC Treasury Department, Raleigh, NC.

City of Raleigh. (2001). Raleigh 2000 Budget, NC Treasury Department, Raleigh, NC.

Creech, J.M. (1979). "History of Greene County, North Carolina", Gateway Press, Baltimore, 705 pages.

CP&L engineer. (2001). personal communication, Kinston, NC.

Electricities Executives. (2001). personal communications, Electricities, Raleigh, NC

Hookerton Mayor, (2000), personal communication, Hookerton, NC.

Hookerton residents. (2001). personal communication, Hookerton, NC.

NC **Rural Center**. (2001). personal communication with environmental personnel, Raleigh, NC.

North **Carolina Environmental Management Commission**, (1998), Hookerton Special Order of Consent, Hookerton, NC.

------. (2001). List of Communities Under SOC, 2001, NCEMC, Raleigh, NC.

Proterra executives. (2001). personal communications, Proterra, Minneapolis, MN.

Skillicorn, P, Spira, W. and **W. Journey.** (1993). DUCKWEED AQUACULTURE: A New Aquatic Farming System for Developing Countries, EMENA, The World Bank.

Town of Hookerton, (1999a), *Hookerton Proposal to Clean Water Management Trust Fund*, NCCWMTF, Greenville, NC.

——, (1999b), *Hookerton Proposal to NC Revolving Loan & Grants Fund*, NCRLGF, Raleigh, NC

——, (2001a), *Hookerton Duckweed WWT Design*, Hookerton, NC.

——, (2001b), *Hookerton 2000 Budget*, NC Treasury Department, Raleigh, NC.

Town of Pink Hill. (2001). *Pink Hill 2000 Budget*, NC Treasury Department, Raleigh, NC.
Town of Snow Hill. (2001). *Snow Hill 2000 Budget*, NC Treasury Department, Raleigh, NC.
Town of Mt. Olive. (2001). *Mt. Olive 2000 Budget*, NC Treasury Department, Raleigh, NC.